

Population Dynamics of *Aphis glycines* (Homoptera: Aphididae) and Its Natural Enemies in Soybean in Northern China

JIAN LIU,^{1,2} KONGMING WU,¹ KEITH R. HOPPER,³ AND KUIJUN ZHAO²

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ABSTRACT A field survey of soybean aphid, *Aphis glycines* Matsumura, and its natural enemies was conducted during summer 2002 in Langfang, northern China (116.4° E, 39.3° N). Aphids colonized soybean when plants were still small in early July. After a lag of 2 wk, aphid density increased rapidly in late July, reaching a peak of 114 ± 46 aphids per five soybean plants on 1 August. The population declined to a plateau immediately after this peak and then declined again starting in mid-August, although a second small peak occurred in late August. The finite rate of increase varied from zero to five-fold, and the aphid seemed to be limited by natural enemies. The main species of natural enemy were the aphid parasitoid *Lysiphlebus* sp., the aphid predators *Propylaea japonica* (Thunberg), *Scymnus* (*Neopullus*) *babai* Sasaji, and *Paragus tibialis* (Fallén). In a field enclosure experiment, *A. glycines* density in small-mesh cages peaked three-fold higher than in large-mesh cages and 12-fold higher than on uncaged plants, indicating that natural enemies did indeed limit aphid density.

KEY WORDS soybean aphid, population dynamics, natural enemy, enclosure experiment

SOYBEAN, *Glycine max* (L.), which originated in China, is an important crop in the northern and northeastern regions of this country. The soybean aphid, *Aphis glycines* Matsumura, a secondary insect pest of soybean, is found in all soybean-growing regions of China. *A. glycines* occurs frequently in soybean, but little insecticide is used for its control because it rarely reaches economically damaging levels. However, short-lived outbreaks have been reported in some areas, and these have at times caused considerable yield loss, which has led to various control measures (Yu 1999, Wu et al. 2004).

Host plant abundance and natural enemies are major factors that affect the population dynamics of herbivorous insects. *A. glycines* uses few host plant species in China, with the only reported hosts besides *G. max* being the wild soybean, *Glycine Benth* f. *lanceolata* Makino and *Rhamnus davuricus* Pall (Wang et al. 1962, Zhang 1981, Zhang et al. 1983). Although few studies have been done on *A. glycines* in China, the limited evidence suggests that natural enemies play a major role in control of this pest (Young et al. 1994, Li et al. 2000, Xue et al. 2000). Here, we report results of a field survey and an enclosure experiment on *A. glycines* and its natural enemies in northern China.

Materials and Methods

The research was conducted in 2002 at Langfang Experimental Station, Chinese Academy of Agricultural Sciences, in Hebei Province of northern China (116.4° E, 39.3° N). The work included 1) a survey to measure the population dynamics of the aphid and its natural enemies in soybean, and 2) an enclosure experiment to measure natural enemy impact.

Field Survey. The survey was done in a 0.23-ha soybean field (adjacent to cotton) planted with variety Zhonghuang-4 on 10 June after wheat had been harvested. The wheat was harvested in early June and then the field was plowed, fertilized, and irrigated. Soybean seed was planted at 225,000 per ha 1 wk after irrigation. The field was hand weeded periodically. Soybean seedlings emerged 5 d after planting. The plants began to produce flower buds ≈ 20 d later and then began flowering in another 25 d. The plants flowered for ≈ 30 d and pods developed over a 20-d period and then began to mature.

Sampling started on 4 July when alate aphids migrated into the field; at this time, the soybean seedlings were in the two-leaf stage. Twenty locations were selected as fixed sampling sites. Each one consisted of five plants, at least one of which had been colonized by the aphids. Samples were collected every 2 d from 4 July to early September. Each plant was visually examined, and all insects were counted. Mummified aphids were collected, and the numbers of each parasitoid species that emerged was recorded. The parasitoid populations were sufficiently large that the mummies removed during sampling would have little or no effect on parasitoid dynamics.

¹ Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing 100094, China.

² Agricultural College, Northeast Agricultural University, Harbin 150030, China.

³ USDA-ARS, Beneficial Insects Introduction Research Laboratory, Newark, DE 19713.

Enclosure Experiment. The impact of natural enemies on *A. glycines* abundance was measured in an enclosure experiment. This experiment was done in 0.65-ha soybean field planted with variety Zhonghuang-4 on 18 June. To provide aphids for artificial infestation, soybean aphids were collected from this field in late June and were cultured on soybean seedlings in the laboratory. Three levels of natural enemy enclosure were used: small-mesh (1 by 1-mm holes) cages, large-mesh (2 by 2-mm holes) cages, and no cages. Natural enemies had complete access to aphids in the no-cage treatment and limited access to aphids in the caged treatments. Each treatment was replicated six times with 60 plants per replicate. Cages were polyester sacks 1 m in width by 2 m in length by 1.2 m in height, supported on bamboo poles at each corner, with the bottom edge of the sacks buried in the soil. In each replicate, the plants were infested artificially with 20 aphids (apterae and fourth instars) on 26 July. To infest plants, we took soybean plants infested by the aphids in the laboratory to the field and transferred aphids to the experimental plants by using a small brush. Five days before infesting plants with aphids, we removed any resident aphids and natural enemies by spraying with insecticide. To do this, Cyhalothrin (2.5%; ICI Ltd., Runcorn, England) was sprayed from a nozzle held 0.2–0.3 m above the soybean plants by using a backpack sprayer. Spray dose was 5 ppm with a 3–5-s spray on each plant. For small-mesh cages only, each replicate was divided into two 1 by 1-m parts on 4 September. To do this, the cage cover was folded back so that one-half was exposed and the other half of the original cage was left caged. Samples of density were collected every 2 d from 28 July until mid-September. Each plant in each cage was visually examined and all insects were counted. Mummified aphids were collected, and the numbers and species of parasitoids that emerged were recorded. Vouchers of all species are stored at the Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China.

Data Analysis. The aphid densities in the survey data where non-normally distributed and therefore were log transformed for analyses. We tested the impact of sample date on aphid density by using repeated measures, mixed model analysis of variance (ANOVA) with date repeated within location, which was considered a random effect. We also tested the relationship between the growth of the aphid population from one sample date to the next and the density of its natural enemies, using Kendall's nonparametric correlation coefficient.

For the enclosure experiment, we tested the effects of enclosure level, date, and their interaction on aphid density by using repeated measures ANOVA. Sample date was repeated within replicates. We analyzed separately the effect of removing cage covers from one-half of each small-mesh cage. All analyses were done with the SAS program, version 8 (SAS Institute 1999).

Results

Field Survey. *A. glycines* colonized the soybean field at the beginning of July, but aphid density did not increase until 2 wk later (Fig. 1a and b; effect of sample date $F = 31.2$; $df = 34, 646$; $P < 0.0001$). Density increased rapidly in late July, reaching a peak of 114 ± 46 aphids per five soybean plants on 1 August. The population declined to a plateau immediately after this peak and then declined again starting in mid-August. A second small peak occurred in late August. The finite rate of increase varied from zero- to five-fold (Fig. 1a).

Seven natural enemies of *A. glycines* were found in the following numbers: 71 *Lysiphlebus* sp. (Hymenoptera: Braconidae), 50 *Scymnus* (*Neopullus*) *babai* Sasaji, 23 *Propylaea japonica* (Thunberg) (Coleoptera: Coccinellidae), 19 *Paragus tibialis* (Fallén) (Diptera: Syrphidae), five *Chrysopa septempunctata* Wesmael (Neuroptera: Chrysopidae), two *Coccinella septempunctata* L. (Coleoptera: Coccinellidae), and two *Chrysopa sinica* Tjeder (Neuroptera: Chrysopidae). The three most abundant predator species were first observed when aphid numbers began to increase in late July. The density of *S. babai* tracked that of *A. glycines* (Fig. 1c). Although *P. japonica* was found sporadically beginning in late July, it was most abundant in late August (Fig. 1c). The density of *P. tibialis* increased in early August and then declined, probably because of heavy parasitism by the gregarious syrphid parasitoid *Syrphophagus aphidivorus* (Mayr) (Hymenoptera: Encyrtidae), which was found in high numbers (1,329 total) in the latter half of August (Fig. 1d). These patterns suggest that both *S. babai* and *P. tibialis* may have contributed to controlling the aphid in early August, but *P. japonica* may have been more important in late August. Unlike the predators, the aphid parasitoid *Lysiphlebus* sp. was first found at the same time as *A. glycines* in form of mummies in numbers greater than unparasitized aphids (Fig. 1e). Parasitized aphids were not found again until late July, after aphid density increased. The rate of increase of *A. glycines* did not correlate with the density of any of these natural enemies (Kendall's tau; $P > 0.05$).

Enclosure Experiment. *A. glycines* density in small-mesh cages peaked three-fold higher than in the large-mesh cages and 12-fold higher on uncaged plants (Fig. 2; for differences among enclosure levels, $F = 78.6$; $df = 2, 15$; $P < 0.0001$). Aphid density in all treatments increased almost exponentially in first week after infestation (Fig. 2). Density on plants in small mesh cages declined after 8 September, as plant quality deteriorated, but density on uncaged plants started to decline by 3 August, and density on plants in large-mesh cages begin to decline by 15 August (Fig. 2; for interaction between enclosure and date, $F = 15.2$; $df = 54, 391$; $P < 0.0001$).

Eight enemies were found in large-mesh cages and on uncaged plants. In addition to *P. japonica*, *C. septempunctata*, and *C. sinica*, which were found in the field survey, we also found *Epistrophe balteata* De Geer (Diptera: Syrphidae), *Orius similis* Zheng, *Geo-*

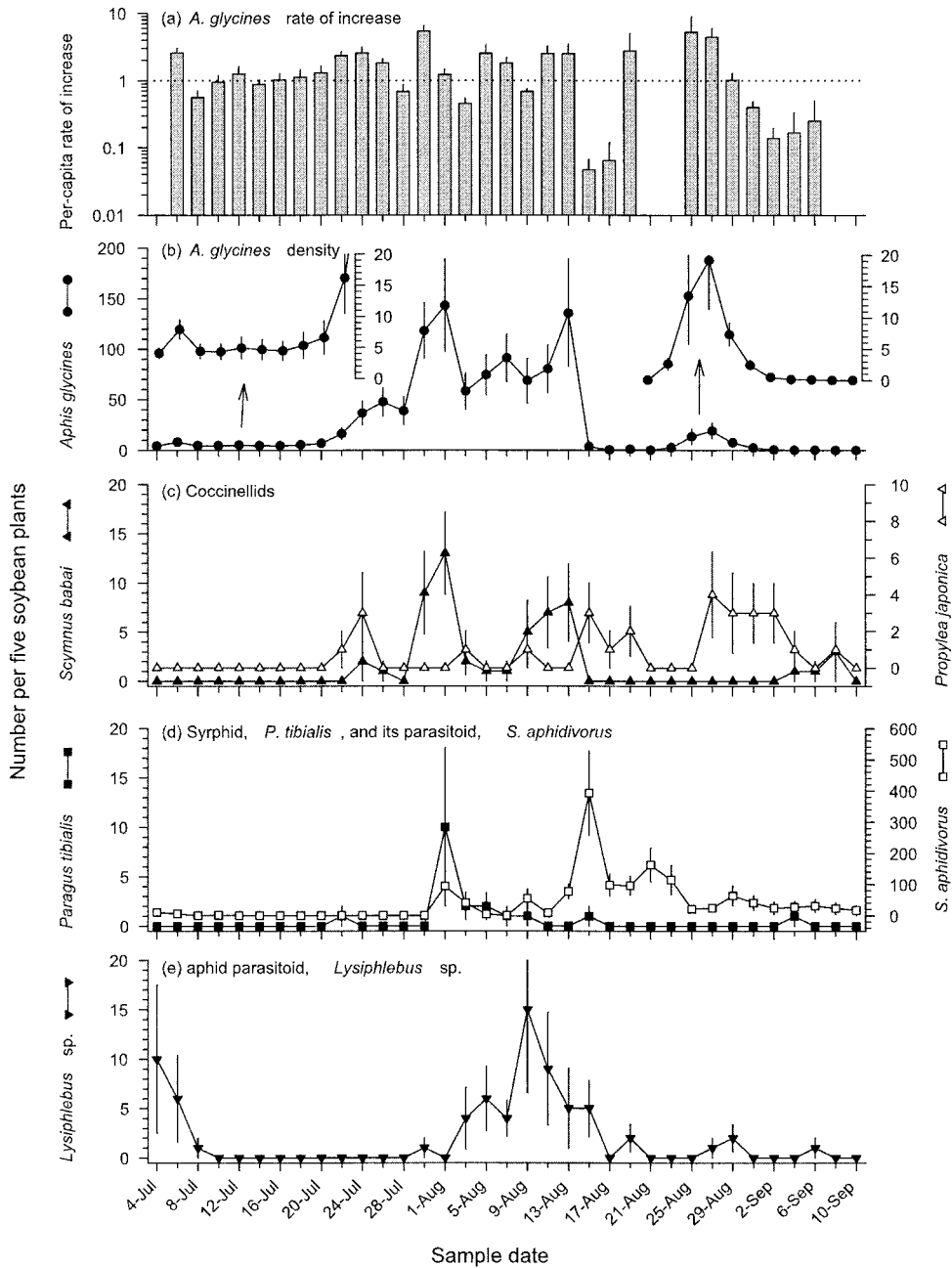


Fig. 1. Population dynamics of *A. glycines* and its natural enemies in Langfang, 2002. Vertical bars are standard errors of the means.

coris pallidipennis (Costa), *Deraeocoris punctulatus* (Fallén), and *Nabis palliferus* Hsiao (Hemiptera). *Propylea japonica* was the most abundant with densities as high as 25 per 100 plants.

When cage covers were removed from one-half of the plants in small-mesh cages, *A. glycines* density declined more rapidly in the uncaged part than that in caged part (Fig. 2; $F = 89.9$; $df = 1, 6$; $P < 0.0001$). One week after the cage was removed, *A. glycines* density

on plants where the cage was removed was one-third that found on plants still covered.

Discussion

The lag between colonization and increase of *A. glycines* density could have arisen in part because alates arrived, reproduced, and died, and their progeny took a couple of weeks to reach reproductive

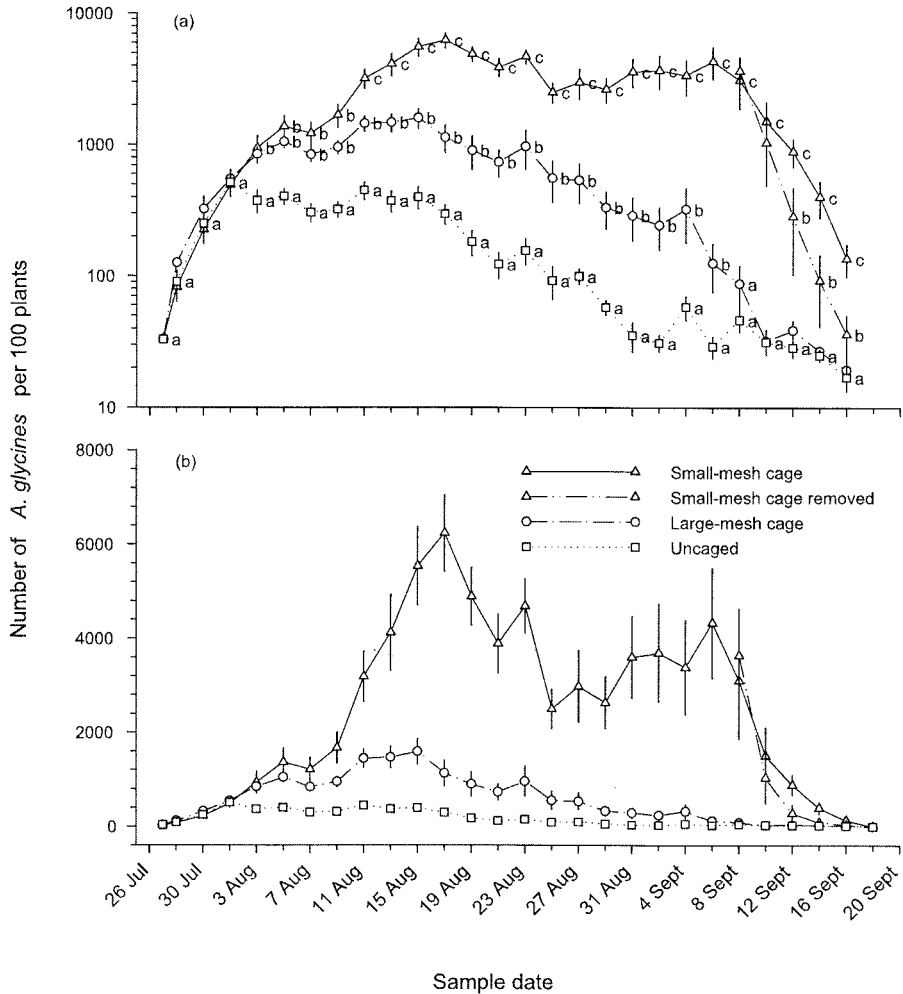


Fig. 2. Dynamics of *A. glycines* under various levels of natural enemy enclosure. (a) Logarithmic scale, points with common letter indicate no difference between means for a sample date. (b) Arithmetic scale. Vertical bars are standard errors of the means.

maturity. The several occasions when aphid density rose very rapidly suggest additional immigrations of aphids. The high proportion of parasitized aphids among those found at the beginning of aphid colonization suggests that a large proportion of the early colonizing aphids were parasitized.

Three hypotheses could explain the greater growth rate of *A. glycines* populations in small-mesh cages: 1) microclimate may have differed among treatments, and the differences could have affected aphid reproduction or survival; 2) cages may have reduced aphid emigration, causing aphid density to build up; and 3) cages may have reduced aphid mortality by excluding natural enemies. Although experiments on *Diuraphis noxia* (Mordvilko) with similar cages eliminated hypotheses one and two (Hopper et al. 1995), these explanations might still apply here. However, blocked emigration does not explain the build up of aphids in large mesh cages here because aphid density was much higher in large-mesh cages than without cages,

yet aphids could easily disperse from large-mesh cages. Several natural enemies were found in large-mesh cages and on uncaged plants, and no natural enemies were found in the small-mesh cages. Thus, these natural enemies were evidently able to enter and leave large-mesh cages, and the density of aphids was much lower in these than in the small-mesh cages. Although the density of natural enemies in large-mesh cages and on uncaged plants was low, the density of *A. glycines* in these treatments was also low, which may have meant that predators and parasitoids did not linger to be sampled. The high aphid density on plants where small-mesh cages were removed was associated with a high density of *P. japonica*, suggesting that this predator at least responded to aphid density.

We found 12 species of natural enemies of *A. glycines* in this research, none of them predominating at all times in all samples. These natural enemies are common in cotton (Anonymous 1980), and because our fields were adjacent to cotton it is likely they came

from this cotton. Wang and Ba (1998) found that the density of natural enemies of *A. glycines* reached higher levels in soybean interplanted with maize, *Zea mays* L., than where soybean was planted alone. Thus, crop diversity may increase biological control of *A. glycines* by providing a diversity of predator and parasitoids. The densities of *A. glycines* observed in this field survey were far lower than those observed in the United States, which together with the impact of natural enemies in the enclosure experiment, indicates that biological control is a promising strategy for management of *A. glycines* in the United States.

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